Preplanned Studies

An Analysis of Life-Year Lost Due to COVID-19 — 34 Countries, December 2019–March 2021

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Summary

What is already known about this topic?

The coronavirus disease 2019 (COVID-19) pandemic has caused severe health consequences. Though most COVID-19 deaths occurred among very old people, their life-year loss might be very large because of their life expectancy at that age.

What is added by this report?

This study quantified how many years of life were lost due to COVID-19 in 34 countries. COVID-19 caused 9 to 21 years of life lost (YLL) per deceased patient. East Asia and Oceania had substantially lower per capita YLL than North America and Europe. Among all countries included, the United States had the greatest total YLL, Peru had the largest YLL per 100,000 people, and Mexico had the largest YLL per 100,000 COVID-19 patients.

What are the implications for public health practice?

The YLL quantification indicated that the vulnerable population, especially the elderly, should be protected under careful public health measures to reduce their YLL. It also implied that it might be too early to lift anti-epidemic restrictions now, since the extreme disproportionate consequences (total and per-capita YLL) in different countries underscored the scrutinization over the variation in disease control strategies to optimize future disease control and prevention.

The coronavirus disease 2019 (COVID-19) pandemic has caused severe health consequences. This study aimed to estimate the years of life lost (YLL) associated with COVID-19 in different countries. We collected data on COVID-19 cases and deaths up to March 27, 2021 and used a method recommended by the World Health Organization (WHO) to calculate YLL. We assessed the total YLL of each included country and calculated the YLL per 100,000 patients and per 100,000 people. We included 34 countries in the analysis. The US had the greatest total YLL among all countries. Peru topped the per-capita YLL. Mexico suffered from the greatest YLL per 100,000 patients. COVID-19 caused 9 to 21 YLL per deceased patient. East Asia and Oceania had substantially lower per capita YLL than North America and Europe. The pandemic caused disproportionate consequences (total and per-capita YLL) in different countries, implying that the variation in disease control strategies should be scrutinized to optimize future disease control and prevention.

As of November 2021, over 255 million COVID-19 cases were confirmed globally, almost 3 million of whom lost their lives (*1*). The spread of the virus remains fast. While numerous studies have provided insights into COVID-19-related mortality, very few emphasized the life expectancies and life-year loss of the deceased. Some argued that the majority of COVID-19 deaths occurred among the "oldest-old" who were proximal to death even without COVID-19 (*2*). However, the life-year loss of such individuals might be large given their life expectancy at that age (*3*). Estimating the COVID-19-related life-year loss is important to understand the societal loss and to inform the choice of epidemic containment strategies. YLL, an established measure to assess the impact of premature death, captures the additional time a patient would have lived if the patient did not die prematurely (*4*). It refers to the difference between the age of death and the life expectancy at that age. Compared with crude mortality and the number of deaths, YLL aims to comprehensively measure the disease burden. There is an absence of cross-country comparison to provide a worldwide landscape of YLL due to COVID-19 (*5*). This study aimed to provide YLL information for the debate and reflection on the anti-epidemic strategies and the establishment of a comprehensive loss function of COVID-19.

We categorized the COVID-19 patients and population into 9 age groups. The calculation of YLL followed the recommendation by the World Health Organization (Supplementary Materials, available in https://weekly.chinacdc.cn/). Accordingly, we

calculated the primary outcomes, including YLL per 100,000 COVID-19 patients and per 100,000 people. Standard errors were estimated using Monte Carlo simulation with 1,000 repetitions standard errors were estimated using Monte Carlo simulation with 1,000 repetitions (*6*–*7*). We assumed that the death events were uniformly distributed within each age group, so that we were able to approximate the YLL of each group by multiplying the number of deaths and the life expectancy of the median age of the group (e.g., the life expectancy of age 4.5 represented the mean life expectancy of group 0–9). We collected data of the life expectancy of different ages, demographic data of different countries, COVID-19 cases, deaths, and their age distributions (Supplementary Table S1 available in https://weekly.chinacdc.cn/). We included countries with age-specific data available on the incidence and mortality of COVID-19 as of March 2021. Two analysts collected data independently and cross-checked the data. We used Excel 2016 (Microsoft Corporation, United States, North America) and Crystal Ball (version 11.1.1, Oracle Corporation, United States, North America) for analysis and Monte Carlo simulation.

We developed some secondary outcomes using primary outcomes. By dividing YLL per 100,000 patients and deaths per 100,000 patients, we derived YLL per dead patient, indicating the average YLL for every death caused by COVID-19. The 95% credible interval of YLL per dead patient was calculated by simulating the numerator and denominator simultaneously using Monte Carlo simulation 1,000 times. Moreover, by combining the results of countries in the same continental region, we compared the outcomes in five regions: East Asia, Southeast Asia, Europe, North America, and Oceania.

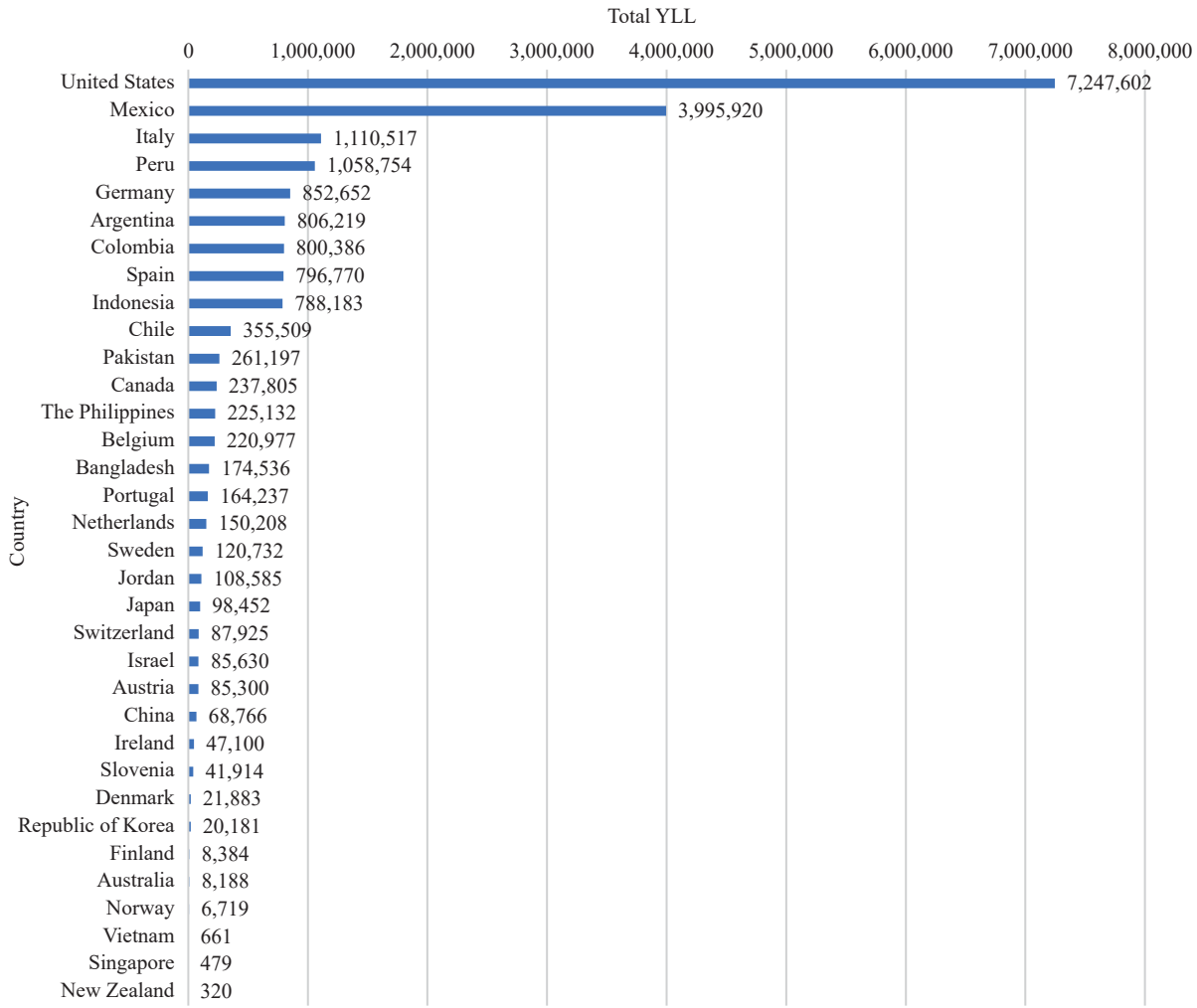

FIGURE 1. Total years of life lost caused by COVID-19 by country.
Note: Countries are sorted in an order of decreasing YLL per 100,000 people.

Among the 34 included countries, the total YLL in the US (7.2 million) was substantially greater than in other countries, almost twice as much as in Mexico (3.99 million). Italy, Peru, Germany, Argentina, Colombia, Spain, and Indonesia had around 1 million YLL. Other countries included had less than 0.36 million. Vietnam, Singapore, and New Zealand had less than 1,000 YLL (Figure 1).

Figure 2 presented the cases, deaths, and YLL for every 100,000 people, in which countries were sorted in an order of decreasing YLL numbers. Peru, Mexico, and the US ranked in the top three in terms of YLL per 100,000 people. Although Peru and Mexico had much fewer per-capita cases than the US, they had similar COVID-19-relevant death rates, leading to a great loss of life years.

Countries with high cases and death rates per 100,000 people usually had a greater loss of life years per 100,000 people, compared with those with low cases and death rates; and vice versa (Supplementary Table S2, available in https://weekly.chinacdc.cn/). For example, Slovenia ranked top in terms of COVID-19 cases and deaths per 100,000 people and ranked fourth in per-capita YLL. Belgium ranked second in terms of deaths per 100,000 people and ranked fifth in per-capita YLL. As the first country reporting COVID-19, China's infection and death rates and YLL per capita were among the lowest in the countries included in the analysis.

Some exceptions existed. Although Israel ranked second in terms of infection rate, the death rate was low (71.2 per 100,000 people), leading to a moderate per-capita YLL (989.3). Among countries with lower than 100 YLL per capita, Singapore had a per-capita YLL as low as 8.2, despite that the infection rate in the country was higher than in other countries of this group. This might be because of its low mortality rate among the confirmed cases.

Figure 3 illustrated the YLL by continental region, in which the circle size was indicated by YLL per 100,000 people. With a much more population than other regions, East Asia had a low total YLL, leading to the lowest YLL per 100,000 people. In contrast, North America had the largest total YLL, though its population size was much smaller than that of East Asia. East Asian and Oceanic countries endured the smallest YLL for every 100,000 people (<30).

Supplementary Figure S1 (available in https://weekly.chinacdc.cn/) illustrated the results of YLL for every 100,000 COVID-19 patients by country. Mexico ranked first on both indicators. As the first country to report COVID-19, China ranked second and had a higher mortality rate and YLL per 100,000 patients than other countries except for Mexico. The US had a moderate death rate and YLL per 100,000 patients. The European countries had YLL ranging from 7,000 to 32,000 for every 100,000 patients. Italy had the highest YLL per 100,000 patients in Europe (31,833), while Norway had the lowest (7,389). Singapore had the least deaths and the lowest YLL per 100,000 patients among all countries. Generally, developing countries had a higher death rate and a higher per-patient YLL than developed countries. Supplementary Table S3 (available in https://weekly.chinacdc.cn/) demonstrated that the deceased patients lost 9 to 21 years of life on average across countries. Australia had the lowest per-patient YLL (9.008), while Peru had the highest per-patient YLL (20.75).

DISCUSSION

This analysis provided a landscape of COVID-19-related YLL accumulated from the start of the pandemic to March 2021 in 34 countries based on age-specific life expectancy. North America had a greater amount of YLL than other regions, and the US ranked first in terms of total YLL among the countries. East Asian and Oceanic countries had a lower per-capita YLL than other countries. The pandemic had caused 9 to 21 years of life lost for every deceased patient on average.

The YLL per deceased patient reminds us how life-threatening this disease could be. We call attention to the fact that COVID-19 patients may die long before their "time," although the crude mortality does not seem as scary as many other fatal diseases. It may be better to shield the vulnerable population, including the elderly and people with underlying diseases, instead of treating them carelessly (*8*).

It was reported that China, Republic of Korea, Norway, and Germany responded relatively faster than other countries since their respective first reported death cases and took a short time to enforce social distancing and contact tracing nationwide (*9*). In contrast, Spain responded relatively slowly to the initial outbreak, whereas Sweden did not take strict measures to limit the transmission (*9*). We observed that East Asian countries, Norway, and Germany had lower YLL per 100,000 people than those with slow response and/or lax measures, such as Spain. The YLL comparison may underline the importance of future research on quick response to COVID-19 and its health burden such as YLL, which may contribute to the consensus on appropriate anti-pandemic strategies.

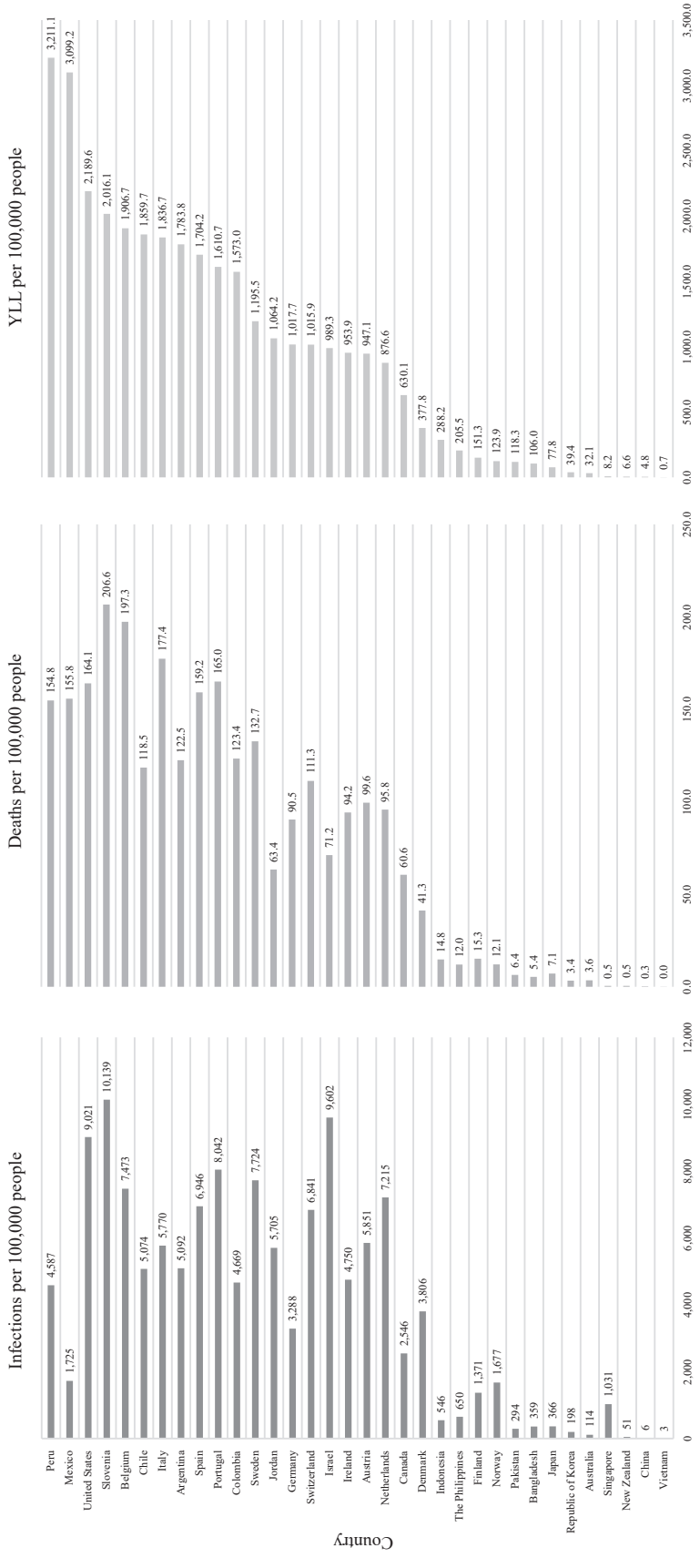

FIGURE 2. COVID-19 cases, deaths and years of life lost (YLL) for every 100,000 people by country.
Note: Countries are sorted in an order of decreasing YLL per 100,000 people.

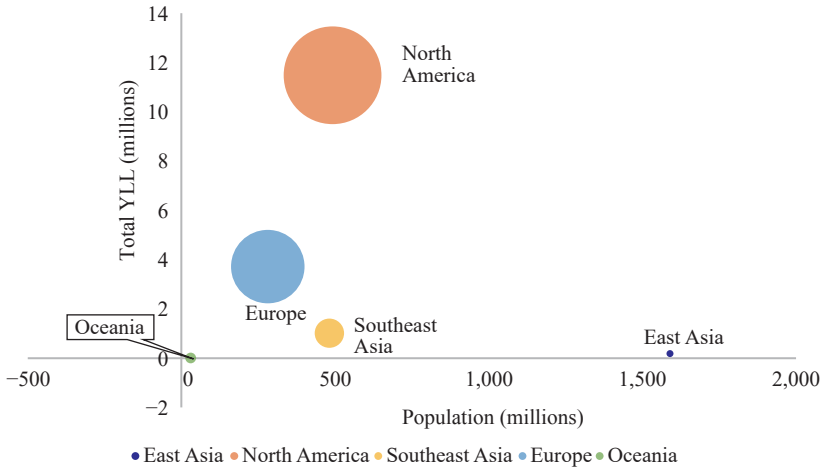

FIGURE 3. Total years of life lost (YLL) due to COVID-19 in some continental regions.

The pandemic continues and the virus keeps mutating. The current predominant pandemic in many countries is caused by the Delta and Omicron variants of coronavirus, which have greater transmissibility than previous variants. Many governments chose to reopen their countries to alleviate the negative impact on the economy of the pandemic. According to the YLL comparison and previous experience (*10*), it might be too early to lift anti-epidemic restrictions, especially when evidence indicates that vaccination and medication may significantly change the landscape of YLL and save lives (*11–12*).

The findings of the present analysis should be interpreted with several caveats, including potential underreporting or misclassification of COVID-19 deaths, the heterogeneous data reporting routines across countries, and the exclusion of many countries due to the absence of key data components. Future research should improve data quality and the scope of analyses.

The pandemic caused different total and per-capita life-year losses in different countries. The variation in disease control strategies underlying such disproportionate consequences should be scrutinized to optimize future efforts in disease control and prevention.

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Supplementary Materials

The COVID-19 patients and population into 9 age groups were categorized (i.e., 0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, and 80 and above). The calculation of YLL followed the recommendation by the World Health Organization (WHO):

$$YLL = \sum_{i=1}^{n} (D_i \times L_i) \quad (1)$$

where n denotes the number of age groups, D_i is the number of deaths due to COVID-19 in age group i, and L_i is the life expectancy of age group i.

According to equation 1 and the age groups we defined, we developed the calculation of YLL per 100,000 COVID-19 patients and per 100,000 people as follows:

$$YLL\ per\ 100,000\ patients = \sum_{i=1}^{9} (p_i \times 100,000 \times \mu_i \times L_i) \quad (2)$$

$$YLL\ per\ 100,000\ people = \sum_{i=1}^{9} (P_i \times 100,000 \times \mu_i \times L_i) \quad (3)$$

where μ_i denotes the mortality rate in age group i due to COVID-19; p_i denotes the proportion of COVID-19 patients in age group i among patients of all age groups; P_i denotes the probability of COVID-19 cases in age group i, which was calculated as the quotient of the number of cases and the number of people in group i. Standard errors were estimated using Monte Carlo simulation with 1,000 repetitions (*1–2*).

We assumed that the death events were uniformly distributed within each age group, so that we were able to approximate the YLL of each group by multiplying the number of deaths and the life expectancy of the median age of the group (e.g., the life expectancy of age 4.5 represented the mean life expectancy of group 0–9). The life expectancy of different ages was from the WHO country-specific lifetables (*3*). The demographic data of different countries were from the United Nations World Population Prospects in 2019 (*4*). We collected data on COVID-19 cases, deaths, and their age distributions from January 1, 2020 to March 27, 2021, using data from WHO and corresponding countries and regions (*5–7*). We used Microsoft Excel 2016 (Microsoft Corporation, United States, North America) and Oracle Crystal Ball (version 11.1.1 Oracle Corporation, United States, North America) for analysis and Monte Carlo simulation.

We included countries with age-specific data available on the incidence and mortality of COVID-19 as of March 2021. When the data on the age distribution of COVID-19 cases and deaths exactly as of March 27, 2021, were not available, the information with the closest time stamp was carried forward. Due to the lack of information, the age distributions of confirmed cases in the UK were imputed using the pooled data of England and Scotland. When the age groups of the source data in a certain country were not defined coherently with the present analysis, they were mapped to the age groups defined in the present study by assuming a uniform distribution of cases within each age group in the source data. Data on the age distribution of the general population and the life expectancy of included countries were retrieved from PopulationPyramid.net, government websites, and WHO (*1–2*). Two analysts collected the data independently and cross-checked the data.

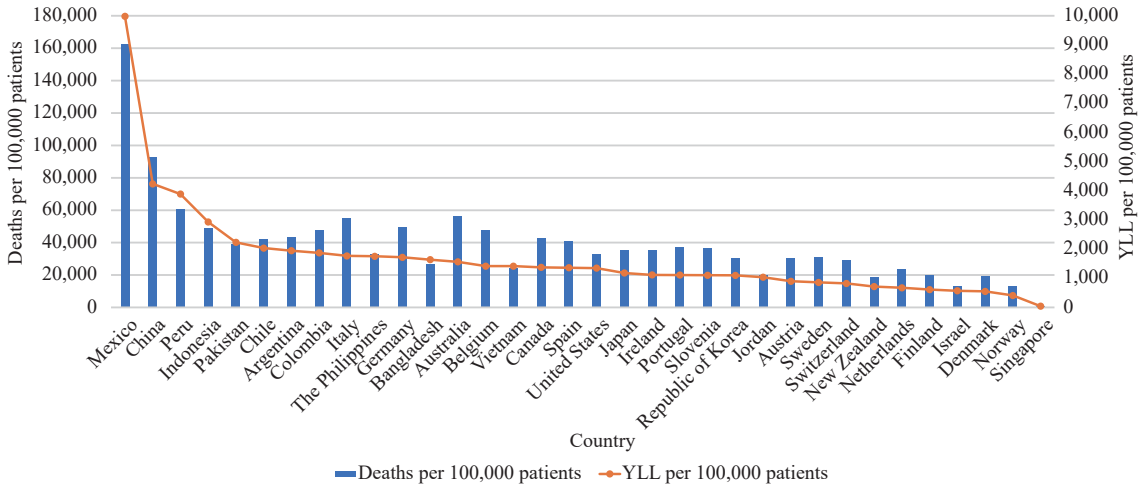
We developed secondary outcomes using primary outcomes such as deaths, YLL per 100,000 people, and YLL per 100,000 patients. By dividing YLL per 100,000 patients and deaths per 100,000 patients, we derived YLL per dead patient, indicating the average YLL for every death caused by COVID-19. The 95% confidence interval of YLL per dead patient was calculated by simulating the numerator and denominator simultaneously using Monte Carlo simulation 1,000 times. Moreover, we categorized the countries into eight regions: East Asia, Southeast Asia, South Asia, West Asia, Europe, North America, South America, and Oceania. We derived regional YLL outcomes by combining the results of countries in the same region. We extracted the data on COVID-19 cases and deaths from the sources listed Supplementary Table S1.

SUPPLEMENTARY TABLE S1. Data sources for COVID-19 cases and deaths in different countries.

Country/Region	Diagnosis	Death	Data reference
China	90,167	4,636	(*8*,*9*)
Italy	3,488,619	107,256	(*10*)
Republic of Korea	101,757	1,722	(*11*)
Spain	3,247,738	74,420	(*12*)
Germany	2,755,225	75,780	(*13*)

TABLE S1. (Continued)

Country/Region	Diagnosis	Death	Data reference
United States	29,859,706	543,003	(*14*,*15*)
Sweden	780,018	13,402	(*16*)
Norway	90,934	656	(*17*)
Australia	29,071	909	(*18*)
Canada	961,083	22,852	(*19*)
Singapore	60,288	30	(*20*,*21*)
Denmark	220,459	2,391	(*22*)
Japan	462,459	9,028	(*23*)
Portugal	820,042	16,827	(*22*)
Netherlands	1,236,209	16,421	(*24*)
Switzerland	592,090	9,631	(*25*)
Mexico	2,224,261	200,862	(*22*)
Vietnam	2,590	35	(*22*)
The Philippines	712,442	13,159	(*22*)
Bangladesh	591,214	8,878	(*22*)
Indonesia	1,494,589	40,449	(*22*)
Belgium	866,063	22,870	(*26*)
Austria	526,948	8,968	(*22*)
Chile	969,913	22,653	(*22*)
Peru	1,512,384	51,032	(*22*)
Israel	649,824	14,158	(*27*)
Finland	831,084	6,165	(*22*)
Pakistan	75,973	845	(*22*)
Argentina	2,375,591	62,790	(*22*)
Colombia	2,301,389	55,368	(*22*)
Jordan	582,133	6,472	(*22*)
Ireland	234,556	4,653	(*28*)
New Zealand	2,482	26	(*29*)
Slovenia	210,787	4,296	(*30*)



SUPPLEMENTARY FIGURE S1. Deaths and years of life lost for every 100,000 COVID patients.

SUPPLEMENTARY TABLE S2. COVID-19 cases, deaths, and years of life lost for every 100,000 people by country.

Country	Cases per 100,000 people	95% CI lower	95% CI upper	Deaths per 100,000 people	95% CI lower	95% CI upper	YLL per 100,000 people	95% CI lower	95% CI upper
Argentina	5,092	5,086	5,098	123	121	123	1,783.8	1,766.1	1,800.3
Australia	114	113	115	4	3	4	32.1	29.7	34.5
Austria	5,851	5,836	5,867	100	98	102	947.1	926.5	970.6
Bangladesh	359	358	360	5	5	5	106.0	103.4	108.2
Belgium	7,473	7,457	7,489	197	195	200	1,906.7	1,877.9	1,936.0
Canada	2,546	2,541	2,551	61	60	61	630.1	620.5	639.5
Chile	5,074	5,063	5,083	119	117	120	1,859.7	1,832.2	1,889.8
China	6	6	6	0	0	0	4.8	4.6	4.9
Colombia	4,669	4,663	4,675	123	122	124	1,573.0	1,556.9	1,588.2
Denmark	3,806	3,790	3,821	41	40	43	377.8	361.7	396.0
Finland	1,371	1,361	1,380	15	14	16	151.3	138.0	163.5
Germany	3,288	3,285	3,292	90	90	91	1,017.7	1,008.7	1,025.7
Indonesia	546	546	547	15	15	15	288.2	284.4	290.9
Ireland	4,750	4,731	4,769	94	91	97	953.9	917.3	989.8
Israel	9,602	9,581	9,620	71	70	73	989.3	960.5	1,018.8
Italy	5,770	5,764	5,776	177	176	178	1,836.7	1,824.1	1,850.2
Japan	366	365	367	7	7	7	77.8	76.1	79.6
Jordan	5,705	5,691	5,721	63	62	65	1,064.2	1,036.0	1,093.9
Mexico	1,725	1,723	1,727	156	155	156	3,099.2	3,083.4	3,114.2
Netherlands	7,215	7,202	7,227	96	94	97	876.6	862.0	893.1
New Zealand	51	49	54	1	0	1	6.6	3.7	9.5
Norway	1,677	1,667	1,688	12	11	13	123.9	112.7	135.7
Pakistan	294	293	295	6	6	7	118.3	115.4	120.0
Peru	4,587	4,581	4,596	155	154	156	3,211.1	3,181.2	3,243.4
The Philippines	650	649	652	12	12	12	205.5	201.1	209.6
Portugal	8,042	8,025	8,060	165	163	168	1,610.7	1,582.3	1,640.7
Singapore	1,031	1,023	1,038	1	0	1	8.2	4.7	11.6
Slovenia	10,139	10,099	10,180	207	201	213	2,016.1	1,942.6	2,086.2
Republic of Korea	198	197	200	3	3	4	39.4	36.9	41.3
Spain	6,946	6,939	6,953	159	158	160	1,704.2	1,690.2	1,718.6
Sweden	7,724	7,706	7,740	133	131	135	1,195.5	1,169.0	1,219.0
Switzerland	6,841	6,825	6,859	111	109	113	1,015.9	991.6	1,039.7
United States	9,021	9,018	9,024	164	164	164	2,189.6	2,182.7	2,196.3
Vietnam	3	3	3	0	0	0	0.7	0.4	0.9

Note: “Lower” means the lower bound of confidence interval (CI); “upper” means the upper bound of CI.
Abbreviations: 95% CI=95% confidence interval; YLL=years of life lost

SUPPLEMENTARY TABLE S3. Deaths and years of life lost per 100,000 COVID-19 patients by country and years of life lost per death caused by COVID.

Country	Deaths per 100,000 patients	95% CI lower	95% CI upper	YLL per 100,000 patients	95% CI lower	95% CI upper	YLL per death for patients	95% CI lower	95% CI upper
Argentina	2,406	2,387	2,425	35,032	34,688	35,383	14.56	14.41	14.71
Australia	3,127	2,956	3,305	28,166	26,239	30,047	9.01	8.32	9.65
Austria	1,702	1,670	1,734	16,188	15,813	16,559	9.51	9.26	9.76
Bangladesh	1,502	1,472	1,531	29,522	28,779	30,195	19.66	19.14	20.17
Belgium	2,641	2,609	2,672	25,515	25,131	25,897	9.66	9.50	9.80
Canada	2,378	2,349	2,406	24,743	24,397	25,123	10.41	10.25	10.57
Chile	2,336	2,309	2,362	36,654	36,063	37,211	15.69	15.45	15.95
China	5,142	5,014	5,277	76,266	73,865	78,905	14.83	14.31	15.41
Colombia	2,643	2,622	2,662	33,692	33,366	33,982	12.75	12.63	12.88
Denmark	1,085	1,045	1,125	9,926	9,482	10,390	9.15	8.69	9.62
Finland	1,112	1,043	1,180	11,036	10,148	11,888	9.92	9.15	10.80
Germany	2,750	2,733	2,768	30,947	30,723	31,201	11.25	11.15	11.35
Indonesia	2,706	2,678	2,732	52,736	52,086	53,265	19.49	19.23	19.73
Ireland	1,984	1,930	2,038	20,080	19,409	20,814	10.12	9.74	10.50
Israel	742	723	760	10,303	10,000	10,625	13.89	13.44	14.35
Italy	3,074	3,058	3,091	31,833	31,627	32,055	10.35	10.28	10.43
Japan	1,952	1,916	1,989	21,289	20,801	21,772	10.91	10.62	11.17
Jordan	1,112	1,088	1,140	18,653	18,129	19,221	16.78	16.23	17.30
Mexico	9,031	8,996	9,063	179,652	178,838	180,485	19.89	19.79	20.00
Netherlands	1,328	1,308	1,348	12,151	11,933	12,367	9.15	8.97	9.34
New Zealand	1,048	727	1,415	12,910	7,566	18,753	12.32	7.41	19.26
Norway	721	670	773	7,389	6,662	8,085	10.24	9.27	11.37
Pakistan	2,179	893	3,486	40,195	22,251	58,558	18.45	9.54	37.09
Peru	3,374	3,346	3,401	70,006	69,328	70,717	20.75	20.53	20.97
Philippines	1,847	1,817	1,879	31,600	30,924	32,281	17.11	16.71	17.51
Portugal	2,052	2,023	2,081	20,028	19,685	20,387	9.76	9.57	9.93
Singapore	50	32	66	795	457	1,109	15.97	9.99	24.23
Slovenia	2,038	1,981	2,092	19,885	19,208	20,542	9.76	9.42	10.12
Republic of Korea	1,692	1,615	1,764	19,833	18,762	20,762	11.72	11.08	12.41
Spain	2,291	2,274	2,308	24,533	24,289	24,764	10.71	10.59	10.82
Sweden	1,718	1,694	1,742	15,478	15,158	15,763	9.01	8.82	9.21
Switzerland	1,627	1,598	1,657	14,850	14,502	15,188	9.13	8.91	9.34
United States	1,819	1,814	1,823	24,272	24,190	24,346	13.35	13.30	13.39
Vietnam	1,351	941	1,744	25,513	15,696	35,570	18.88	11.94	29.52

Note: "Lower" means the lower bound of confidence interval (CI); "upper" means the upper bound of CI.
Abbreviations: 95% CI=95% confidence interval; YLL=years of life lost.

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